SPREAD SPECTRUM TRANSMITTER AND RECEIVER EMPLOYING COMPOSITE SPREADING CODES

BACKGROUND OF THE INVENTION

The present invention relates to a direct sequence code division multiple access system in spread spectrum communications and, more particularly, to a spread spectrum receiver and transmitter that spreads an input signal by both short-term and long-term spreading codes (hereinafter referred to as short and long codes, respectively).

In recent years, a variety of spread spectrum systems have been studied for more effective frequency utilization in digital mobile radio communications (M. K. Simon, J. K. Omura, R. A. Scholtz and B. K. Levitt, "Spread Spectrum Communication", Computer Science Press, 1985). In particular, a DS-CDMA (Direct Sequence-Code Division Multiple Access) system is relatively simple in configuration and studies have been continued with the goal of putting it to practical use. In the application of the DS-CDMA system to, for example, a cellular mobile radio communication system, the same short code can be used in adjacent cells when different long codes are assigned to them.

In FIG. 1 there is illustrated a prior art example of a transmitter in the DS-CDMA system. A digital signal s(m) is fed via an input terminal **11** to a baseband modulator **12**, which uses the digital signal s(m) to generate a baseband modulated signal b(n). The baseband modulated signal b(n) is applied to a multiplier **14A** forming a spreading part **14**, wherein it is spectrum-spread by being multiplied by a short code SC_S that is fed from a short code generator $\mathbf{13}_S$. The multiplied output is further fed to another multiplier **14B** forming the spreading part **14**, wherein it is again spectrum-spread by being multiplied by a long code SC_L from a long code generator $\mathbf{13}_L$. The chip periods of the short and long codes SC_S and SC_L are both T_C, and the short and long code generators $\mathbf{13}_S$ and $\mathbf{13}_L$ operate on a clock signal CK of a clock frequency $1/T_C$ which is generated by a clock signal generator **17**. A baseband modulated signal $b_{sp}(n)$, which is the output from the multiplier **14B**, is applied to a multiplier **19**, wherein it is up-converted to the RF frequency band by being multiplied by a carrier signal CW from a carrier signal generator **18**, and the multiplier output is amplified by a transmitting amplifier **21**, thereafter being sent as a transmitting modulated wave from an antenna **22**.

The short code SC_S has a code period of the same length as that of the symbol period T_S of the baseband modulated signal b(n) as shown in FIG. 2 and spectrum-spreads respective symbols b(1), b(2), . . . On the other hand, the long code SC_L has a very long period T_L corresponding to tens or hundreds of symbol lengths and is used to randomize signals received from other cells (or zones). The long code is usually a long-term PN (Pseudo Noise) sequence, and the same cell is assigned the same long code and different cells different long codes. Since different long codes have very low correlation, they can be used to randomize received signals from other cells. The short code generator $\mathbf{13}_S$ has, for example, a well-known configuration which EXCLUSIVE ORS outputs from at least two desired shift stages of a shift register and feeds the result of the exclusive ORing back to the input of the shift register. Letting the number of shift stages of the shift register be represented by K, a (2^K-1)-chip pseudo noise code (PN code) which repeats itself with a $(2^K-1)T_C$ period can be generated by driving the shift register with a clock signal of a $1/T_C$-chip rate. The long code generator $\mathbf{13}_L$ can be identical in construction with the short code generator $\mathbf{13}_S$, except that the number of shift stages K is sufficiently larger than that in the latter.

In FIG. 3 there is shown in block form a prior art example of a receiver in the DS-CDMA system. Incidentally, the propagation is assumed to be a two-path Rayleigh fading model and, therefore, its operation will be described on the assumption that the received wave is based on a two-wave model consisting of a direct path and a delayed path. In the first place, the received wave arrives at an antenna **25**. The received wave is amplified by a low-noise amplifier **26** and multiplied in a multiplier **28** by a carrier signal CW from a carrier signal generator **27**, thereafter being fed to a low-pass filter **29**. This operation or manipulation corresponds to down-converting, and the low-pass filter **29** outputs the spread-spectrum baseband modulated signal $b_{sp}(n)$, which is applied to an input terminal $\mathbf{3}_{IN}$ of a multipath separating part **30**. The spread-spectrum baseband modulated signal $b_{sp}(n)$ is branched by a hybrid circuit **31** to two paths corresponding to the two propagation paths and input into despreading parts $\mathbf{32}_1$ and $\mathbf{32}_2$. A multiplier $\mathbf{32A}_1$ forming the despreading part $\mathbf{32}_1$ multiples the spread baseband modulated signal $b_{sp}(n)$ by a short code SC_S from a short code generator $\mathbf{33}_S$ and provides the multiplied output to another multiplier $\mathbf{32B}_1$ forming the despreading part $\mathbf{32}_1$. The multiplier $\mathbf{32B}_1$ further multiplies the input by a long code SC_L from a long code generator $\mathbf{33}_L$ and provides the multiplied output to an integrator $\mathbf{35}_1$, which accumulates the latest multiplied results of the same number as the chip number of the short code. In other words, the integrator $\mathbf{35}_1$ acts just like a low-pass filter that outputs a mean value of a predetermined number of multiplied outputs. These operations corresponds to despreading. These spreading codes SC_S and SC_L have a high auto-correlation and no desired signal can be extracted without coincidence of their timing in transmission and reception. The short code generator $\mathbf{33}_S$ and the long code generator $\mathbf{33}_L$ are driven by a clock signal CK of a clock frequency $1/T_C$ which is generated by a clock signal generator **39**.

Assuming that the spreading codes SC_S and SC_L of the direct path coincide in timing with the spreading codes SC_S and SC_L produced by the short code generator $\mathbf{33}_S$ and the long code generator $\mathbf{33}_L$, the integrator $\mathbf{35}_1$ extracts a path component of the direct path, which is provided as a despread baseband modulated signal $b_1(n)$ to a terminal **31**. Similarly, a multiplier $\mathbf{32A}_2$ forming the despreading part $\mathbf{32}_2$ multiplies the spread baseband modulated signal $b_{sp}(n)$ by a delayed short code SC_S from a delay circuit $\mathbf{36}_S$ and provides the multiplied output to another multiplier $\mathbf{32B}_2$ forming the despreading part $\mathbf{32}_2$. The multiplier $\mathbf{32B}_2$ further multiplies the input multiplied output by a delayed long code from a delay circuit $\mathbf{36}_L$ and provides the multiplied output to an integrator $\mathbf{35}_2$, which provides a despread baseband modulated signal $b_2(n)$ to a terminal $\mathbf{3}_2$. These operations correspond to despreading. When the spreading timing in the received delayed path of the short and long codes coincides with the timing of the delayed short and long codes SC_S and SC_L, a path component of the delayed path is extracted by the integrator $\mathbf{35}_2$ and provided as the despread baseband modulated signal $b_2(n)$ to the terminal $\mathbf{3}_2$ of the multipath separating part **30**.

The hybrid circuit **31**, the spreading parts $\mathbf{32}_1$ and $\mathbf{32}_2$, the integrators $\mathbf{35}_1$ and $\mathbf{35}_2$, the delay circuits $\mathbf{36}_S$ and $\mathbf{36}_L$, the short code generator $\mathbf{33}_S$ and the long code generator $\mathbf{33}_L$ constitute the multipath separating part **30**. A diversity type detecting part **40** inputs thereinto despread baseband modulated signal $b_1(n)$ and $b_2(n)$ for the respective propagation paths, provided from the integrators $\mathbf{35}_1$ and $\mathbf{35}_2$, then